Inspection Report - Special

Printed On: 8/13/2007
Period 2Qr FY 2007
Period End Date: 3/31/07

Inspection Number: SWF031507

Fiscal Year: 2007

Mine Name: Genwal
Period Type: Quarterly

Mine Owner: Andalex/IPA

Inspector: Steve Falk
Active Faces: 1

Operator: Genwal
Accompanied By:

Operator Rep:
Finalize Date: 8/13/2007

Remarks: On Thursday, March 15, 2007, I (Stephen Falk) made a special inspection of the Crandall Canyon Mine to observed adverse conditions in the pillar section. Tom Hurst, Mine Engineer of Genwal, was my company rep.

Tom had called me earlier in the week and informed me of some tough conditions in the one continuous miner section in the North Barrier off Main West. I informed him I would be up on Thursday and look at the section. Upon arrival, we went to the section and I noted conditions.

Recap of events and last inspection.

After UtahAmerican obtained the property in August 06 and withdrew the longwall out of South Crandall along with the development section, the only section left was the section pulling pillars coming out of South Mains. They finished up in October 2006 and moved right up to the North Barrier of West Mains. They drove out four entries all the way out to crosscut 158 where they encountered too great of water inflow that pumps could not control. This was about 400 feet short of the maximum length before running into the extra north entries up from West Mains along the Joe's Valley Fault. They started to extract two of the three pillars in retreat pillar mining with a MSHA approved pillar plan to leave the top pillar and use the top or north entry as the return. They started right at crosscut 158 which is at about 1200 to 1400 foot depth. The 1st quarter FY 2007 inspection, made in mid December had the crew developing out the four entries at crosscut 129 (see SWF121406). At the end of January, Hurst called me to inform me that the section did not go all the way out parallel to Main West in this North Barrier entries as they encountered fractures that had water inflows much greater than available pumping facilities. This was at crosscut 158 which was about 400 feet short of the back end of Main West next to Joe's Valley Fault. I informed them that that was far enough after confirming with MSHA about the water and to go ahead and start pillar retreat as per their MSHA pillar plan for this section. My next inspection on Feb. 27 had them retreat pillar pulling back to crosscut 149 (see SWF022707). This was the last inspection up to this report.

North Barrier Section, West Mains, Hiawatha Seam, Federal Lease UTU-68082

I arrived at the section and was able to get to between 133 and 132 crosscut where there was dangered off tape across the bottom 3 entries. A map of the aftermath with some of my notes written on the map is attached. It shows where pillar coal has spalled out into the entry and the condition of the stoppings along the north entry. I traveled down the north bleeder entry well inby the dangered off area and verified the items on the map. The situation at this section is clear. The section pulling the two bottom pillars on retreat out of this area was experiencing greater stresses on the pillars. This is coinciding with an increase of overburden from about 1400 feet depth back at crosscut 158 to now at crosscuts 137 - 133 where it is about 2000 feet deep. Pillar bumps were increasing and some damage to the stopping to the north bleeder entry were occurring. Genwal tried to stop the stress override and left two rows of pillars at 137 to 135 and then started up again with the south pillar at 134 - 135 crosscuts. Hurst reported that a few large bounces occurred on off shift soon after start up of pillar mining which did most of the damage. Entry ways outby two breaks from the face had extensive rib coal thrown into the entry way. Stress overrides out by the face were very concerning. The bounces had either knocked out or damaged all the stoppings to the north bleeder entry from crosscut 132 inby to crosscut 149. I could only travel the north entry to 143, but the observed conditions were severe. The weight of the area will only be the same or worse as this is under the ridge top on the surface. If Genwal was to try again, they must under law repair all damaged stopping along the north bleeder entry. They would also need to drop back out by the affected area at least 3 crosscuts and build seals that meet standards that are not yet established as a result of the Sego Mine explosion back east. Hurst said the risks are too great that this event will happen again out by should they try pillar pulling again and they can't justify all the extra expensive to repair and establish new seals. I gave them verbal approval to stop retreat mining for the rest of the section. Tom will send a modification to leave the rest of North Barrier and start on the south barrier. I gave them an ok to start on the south barrier as the boundary between UTU-68082 and the state lease runs down the barrier so that only the top or north most entry will be on federal. I asked how they would mine the south barrier and Tom said they are working on the MSHA roof control and ventilation plan amendment for the south barrier but was not sure if Genwal is asking to pull pillars after what they have seen in north barrier. The conditions noted in

North Barrier were adverse and as depicted on the mine map. Prudence dictates that any further mining of this area would result in more of the same and leaving the remaining coal is necessary. We will act on the written request when received for the official record.

Leases

Lease Number	Lessee	Assignee	Status
ROW-UTU-6683			Terminated
ROW-UTU-7797			Terminated
SL-062648	Intermountain Power Agency &	Genwal	Active Mine Works
State ML-21568			Producing
State ML-21569			Active Mine Works
U-54762	Andalex	Genwal	Active Mine Works
UTU-68082	Andalex	Genwal	Producing
UTU-78953	Andalex	Genwal	Producing

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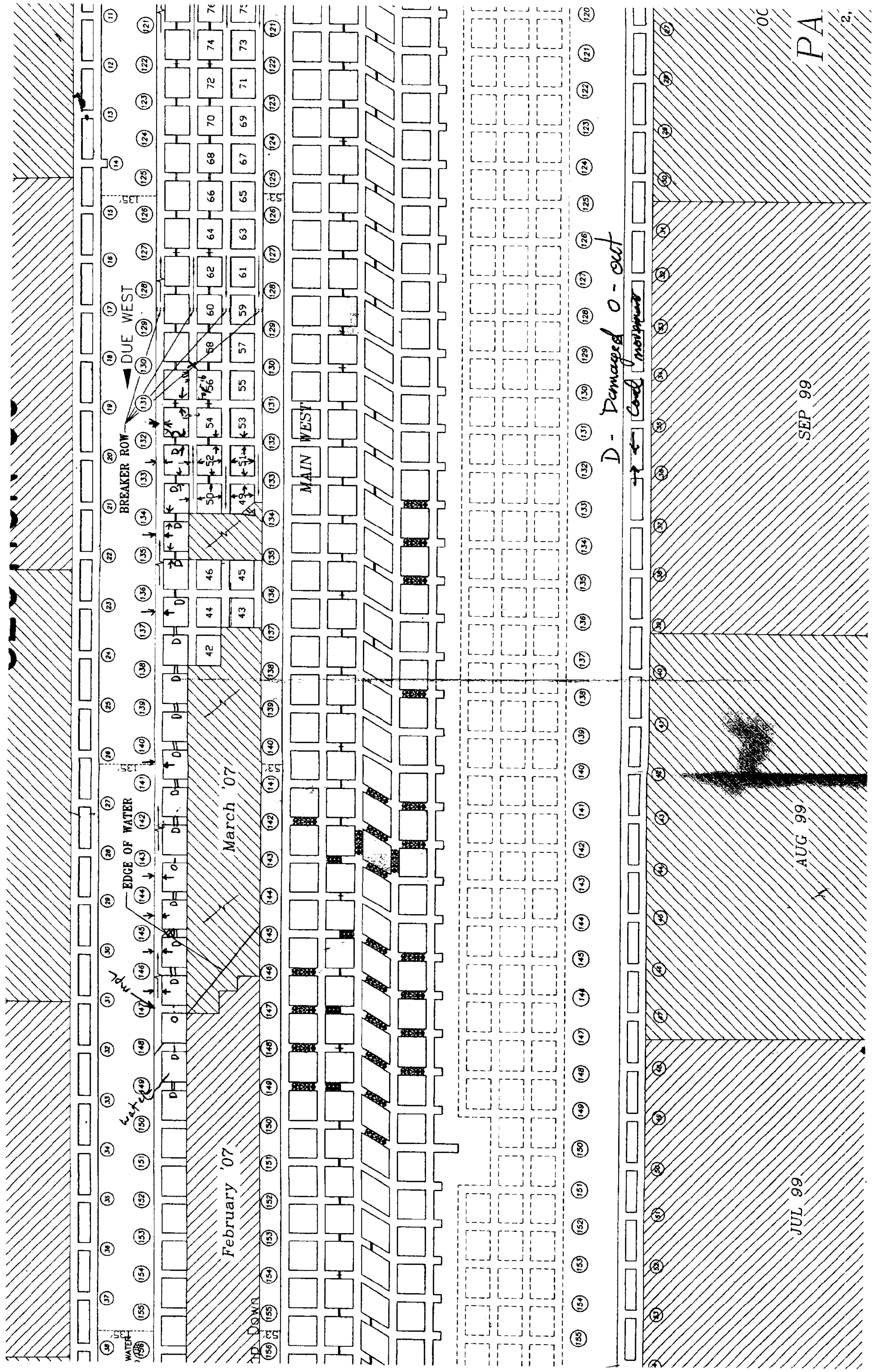
BREAKER ROW
DUE WEST
EDGE OF WATER
MAIN WEST
March '07
February '07
SEP 99
AUG 99
JUL 99
D - Damaged O - out
Coal
WATER

Inspection Report - IE/PV

Printed On: 7/12/2007
Period 2007-Q2
Period End Date: ~~6/30/2007~~ 3/31/07

Inspection Number: SWF022707

Fiscal Year: 2007

Mine Name: Genwal
Period Type: Quarterly
Mine Owner: Andalex/IPA
Inspector: Steve Falk SWF
Active Faces: 1
Operator: Genwal
Accompanied By:
Operator Rep:
Finalize Date: 7/12/2007

Remarks: On Tuesday, February 27, 2007, I (Stephen Falk) inspected the Crandall Canyon Mine, operated by Genwal Coal Company, a subsidiary of UtahAmerican Energy, Inc.. UtahAmerican is a 50 % owner along with Intermountain Power Agency, of the property and lessee of record. Tom Hurst, Senior Mine Engineer, was my company rep.

Just one section is at this mine and personnel are being transferred to other UtahAmerican mines. The section is in the north barrier to Main West. Very little of the coal remains. This section is trying to pull all the remnant coal in the Main West area. Besides the west main pillars and barriers, the only other coal blocks remaining is in the 2nd North area and only if they can mine 5 to 6 feet of clean coal and keep production rates up with one miner section. South Crandall Mine is idled but is ventilated and inspected. Total personnel is down to about 60. The one section is run on a 4 day 10 hour shift with 2 shifts going and a overlapping maintenance shift. Then they have one super weekend shift of 3 day 12 hours. But it seams that Genwal will just finish out with this one section until Lila Canyon comes on line.

The one mining section was visited. Conditions were noted and spot measurements were taken of the section working faces. These measurements will be compared with the submitted monthly production maps to verify volumes from monthly production verification. These spot measurements are shown on the attached maps to this report and will be transferred to the monthly production maps. Genwal is mining according to the approved mine plan and no incidents of non-compliance were noted. The section visited follows below:

North Barrier Section, West Mains, Hiawatha Seam, Federal Lease UTU-68082

This section finished driving 4 entries on 92 foot entry centers and 80 foot crosscut centers. These were driven in the north barrier pillar between Main West and mined out longwall panel # 12. The barrier pillar is 450 foot wide which accommodates the 4 entries. This leaves only 130 foot barrier to the north longwall panel. This section started out back at Main West crosscuts 108 - 110 and drove out to crosscut 158. Here the section starts to dip down to the west before the Joe's Valley Fault. At this place, the section experienced large inflows of water. They could not control it enough with pumps. We think this is water flowing through fractures close to the fault, draining the gob to the north. Crosscut 158 is about 400 feet short of the bleeder entries along the fault. With the water coming in too fast, the company stopped advance at this point and began pulling pillars back. They got a special pillar plan approved by MSHA to pull the south two of three pillars and have the return out the north most entry. So far, the crews have pulled 18 pillars or 9 rows. Currently they are pulling the pillars between crosscut 149 and 150. I have been concerned about pulling pillars in this environment with mining a narrow block with little coal barriers to mined out blocks on both sides. Fortunately, the beginning depth on the west end toward the Joe's Valley Fault is somewhat shallow starting at 1300 feet. So far no inordinate pillar stresses have been noted, though thing should get interesting soon. The face is under 1600 feet of cover now and will increase to over 2000 feet by crosscut 139. The working face looks ok and coal is good. There is some cap rock in the roof that is not holding up during mining. Coal height is running about 9 feet. The rate of retreat mining is well ahead of water build up as the seam has a incline down to the west fault starting with pillar row 144, so the water is running down to the end of the entries. Measurements are noted on the attached map.

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ROW-UTU-6683			Terminated
ROW-UTU-7797			Terminated
SL-062648	Intermountain Power Agency &	Genwal	Active Mine Works
State ML-21568			Producing

State ML-21569			Active Mine Works
U-54762	Andalex	Genwal	Active Mine Works
UTU-68082	Andalex	Genwal	Producing
UTU-78953	Andalex	Genwal	Producing

Was approved plan reviewed?	Yes
Was I&E plan reviewed?	
Was PV plan reviewed?	
Was previous inspection reviewed?	Yes
Was mine status reviewed with MSHA?	No
Was approved plan followed?	Yes
Was a noncompliance encountered?	No
Was an undesirable event encountered?	No
Was the reported production acceptable?	Yes

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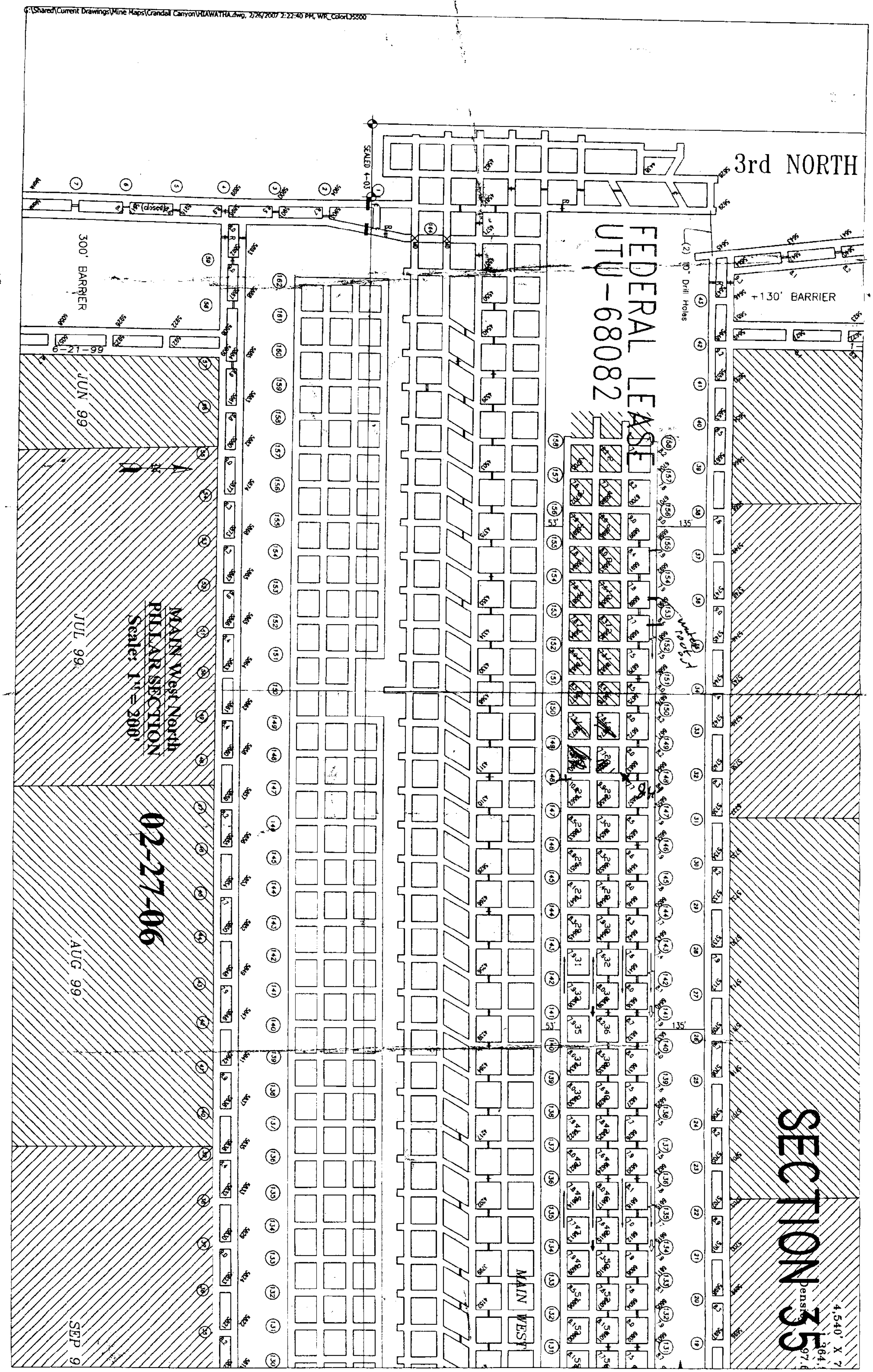
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3rd NORTH
FEDERAL LEASE
UTU-68082
SECTION 35
MAIN West North
PILLAR SECTION
Scale: 1"=200'
02-27-06
SEALED 4-03
300' BARRIER
+130' BARRIER
(2) 10" Drill Holes
6-21-99
JUN 99
JUL 99
AUG 99
SEP 9
MAIN WEST
(closed)

Inspection Report - IE/PV

Printed On: 3/5/2007
Period 2007-Q1

Inspection Number: SWF121406

Mine Name:	Genwal	**Fiscal Year:**	2007
Mine Owner:	Andalex/IPA	**Period Type:**	Quarterly
Inspector:	Steve Falk SWF	**Period End Date:**	~~3/31/2007~~ 12/31/06
Operator:	Genwal	**Active Faces:**	1
Operator Rep:		**Accompanied By:**	
		Finalize Date:	3/5/2007

Remarks: On Thursday, December 14, 2006, I (Stephen Falk) inspected the Crandall Canyon Mine. The owner/lessee is 50/50 percent Andalex Resources and Intermountain Power Agency. Tom Hurst, Mining Engineer for Andalex was my company rep.

The sale of Andalex is complete to Bob Murray's Utah American. They are going to keep the Andalex, Genwal and West Ridge names and companies, who will be subsidiaries of Utah American. A lot of changes have happened. The longwall in South Crandall was halted in mid-August and haul over to West Ridge. The machine will be used on the first panel on the north-west side. This longwall machine has the ability to mine 5.5 feet of coal and the start up face at West Ridge is quite low. The development section was also removed and sent to various other Utah American mines. Mine plan change was submitted to us and we oked the withdraw of the longwall but asked Andalex to update the R2P2 with timing or give more information to justify deletion of all recoverable reserves. Genwal will come in with a new plan for mining much further down the road. So right now Genwal is down to one section. This section finished pulling the South Mains pillars and is now mining out west parallel to Main West in the north barrier. All the other crews have been moved to other operations. South Crandall Mine is idled but is ventilated and maintained.

The one mining section was visited. Conditions were noted and spot measurements were taken of the section workings. These measurements will be compared with the submitted monthly production maps to verify volumes for monthly production verification. These spot measurements are shown on the attached maps to this report and will be transferred to the monthly production maps. Genwal is mining according to the approved mine plan and no incidents of non-compliance were noted. The section visited follows below:

Main West North Barrier, Hiawatha Seam, Crandall Canyon Mine, Federal Coal Lease UTU-68082

Genwal finished up the pillars in South Mains in October. The crew went right to work setting up the section to drive entries in the north barrier of Main West. The crew notched off 3 crosscuts north off of Main West at crosscuts 108, 109 and 110. The first crosscut north is 80 feet center to center. From there, they have mined 3 entries west on 92 entry centers and 80 foot crosscut centers. The original barrier north from Main West up to old longwall panel #12 (1st West headgate) was 450 feet. The new 3 entries in the barrier now would leave a 130 foot barrier to the north gob. They connected up with Main West in each crosscut from 108 through 118. Beyond 118, Genwal just drove the three entries out west without connecting up with the crosscuts to Main West. This was due to the seals erected just inby crosscut 118. If they connected up with Main West inby the seals, they would have to reestablish ventilation through all of Main West. They are now out to crosscut 129. The top or north entry (#4) is the return, # 3 the belt and 2 and 1 the intakes. Coal height is running 9 to 10 feet with the floor in coal of a foot and in pretty good shape. The roof has some laminated top in some areas. Mining height is running about 8 feet. Production is coming from two shifts a day but is running all seven days a week. Tonnages are getting close to 50,000 tons a month. Genwal is going to try and mine all the way out to the fault and then try and get approval to pull back some if not all three pillars. Measurements are shown on the attached map.

Leases

Lease Number	Lessee	Assignee	Status
ROW-UTU-6683			Terminated
ROW-UTU-7797			Producing
SL-062648	Intermountain Power Agency &	Genwal	Active Mine Works
State ML-21568			Producing

State ML-21569			Active Mine Works
U-54762	Andalex	Genwal	Active Mine Works
UTU-68082	Andalex	Genwal	Producing
UTU-78953	Andalex	Genwal	Producing

Was approved plan reviewed?	Yes
Was I&E plan reviewed?	
Was PV plan reviewed?	
Was previous inspection reviewed?	Yes
Was mine status reviewed with MSHA?	No
Was approved plan followed?	Yes
Was a noncompliance encountered?	No
Was an undesirable event encountered?	No
Was the reported production acceptable?	Yes

Close Out Discussion:

This section is mining coal that was not considered minable in the previous plan as Main West was taking weight from both side gobs and Andalex prior to Utah American sealed up Main West at crosscut 118 back in late 2004. Told Tom Hurst that BLM is pleased to have them try for coal that was thought unminable but I warned them to beware of the depth above the ridge and mining a barrier pillar that has been sitting for a number of years. Pulling pillars will be interesting if even MSHA will ok a ventilation and roof control plan for the section.

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Inspection Report - Special

Printed On: 1/24/2005
Period

Inspection Number: SWF110404

		Fiscal Year:	2005
Mine Name:	Genwal	**Period Type:**	Quarterly
Mine Owner:	Andalex/IPA	**Period End Date:**	
Inspector:	Steve Falk	**Active Faces:**	4
Operator:	Genwal	**Accompanied By:**	
Operator Rep:		**Finalize Date:**	1/24/2005

Remarks: On Thursday, November 4, 2004, I (Stephen Falk) inspected the Crandall Canyon Mine, operated by Genwal Resources, Inc., a subsidiary of Andalex, which is a 50 percent owner/lessee along with 50 percent Intermountain Power Agency (IPA). James Sorenson, Mine Engineer for Andalex, was my company rep.

On October 27, 2004, John Lewis, Mining Engineer for Andalex, called and informed me that Genwal would need to seal off the west portion of the Main West mains at the Crandall Canyon Mine. Conditions were deteriorating and access through the area near impossible. I informed him that I would be up the next week to inspect the area. On the 4th of November, I arrived at the mine and James Sorenson was there for the inspection. We went directly to the section with the idea to note conditions and a final inspection of the area before sealing to assure if materials are left or taken out.

Main West is in use up to crosscut 92 where South Mains intersects and accesses 6th East pillar area. Main West continues back west from crosscut 92 to 105 where 1st Right submains drove north to access longwall panels 7-12. This is sealed off. From crosscut 107 to the Joe's Valley Fault at 167, Main West was used as access to the bleeder for longwall panels 13-18. Now this bank of panels is sealed off and use is no longer needed. A number of years ago, BLM inspected Main West after the north longwall block was mined out and the first few panels to the south were mined out. The barrier planned on both sides looked like it was designed to only hold up for only a short while. The north entry was taking weight and extra roof supports and rebolting had to be done. Now the situation is even worse. Genwal plans to seal at 116. At 116, the depth of cover is about 1500 feet and rises to 2000 feet by crosscut 127 and stays 2000+ feet to 143. The depth is between 1500 and 2000 feet from 143 to 154 and drops off to 1000 feet at the fault, 167. It was apparent from traveling down the intake that the area is taking unacceptable weight. Main West is a 5 entry main entry system that was mined to the Joe's Valley Fault back in 1995. The entries were on 90 foot entry and crosscut centers, leaving a 80 x 80 foot pillar. However, the crosscuts from the belt (middle) entry to the left intake (number 2) entry, were driven on an angle off of 90 degrees due to the need for the continuous haulage system then in use to have a easier turn for gathering the track mounted belt. The end result of cutting this crosscut on an angle is that the intersections have tended to be wider and irregular and they are caving in under the pressure. I traveled down the number 1 or left most intake entry and noted the inside pillar rib rash that was occurring past crosscut 123. I peeked past check currents at crosscut 141, 142 and 149 and noted large intersection caves. Genwal is maintaining the left intake but is being told by MSHA that if Main West is to be used in the near future for access, then all travel ways need to be cleaned up and supported against any future caves. It is very apparent that pressure arches from both side gobs are sitting right down on the main entry pillars. At this depth, the pillars are failing. Genwal tried to split a pillar around an intersection cave and could not hold the top and side pillar failures were occurring.

The situation in Main West is untenable for future pillar recovery. No mining company in the area has ever pulled pillars in main entries with mined out sides and under 1500+ feet of cover. That Genwal had thoughts and plans to try pillar recovery was wishful thinking and was more wanting to extend mine life when they failed to get the Mill Fork lease and the need to blend off high sulfur coal from West Ridge.

At the same time, I noted the area for any materials left before sealing. All equipment in the travelable areas had been removed. Belt structure had been also taken out except for a 50 foot section that had been caved on in an intersection. No other materials were noted that had been left. James will file out the haz-mat certification sheets and get them to me.

Close Out Discussion:

Closeout Discussion:

After the inspection, the following items were noted and agreed on. First, Main West past crosscut 116 is no longer of any use and sealing off would release the extra ventilation air for other use. Second, the pillars in Main West are failing over time with greater than 1700 feet of cover. Caves are occurring at intersects compounded by irregular intersection dimensions. Third, attempts to split pillars under this depth could not hold the top and prevent pillar outbursts.

Conclusions: Main West was designed only to hold up until longwall panels were mined out on both sides. Depth of cover precludes pillar recover even if there were no mined out sections next door. Weight on the pillars is substantial and dangerous conditions are present. Mining any of the coal in the pillars will result in hazardous mining conditions such as pillar bursts and roof falls. Original mine plans called for pillar recovery only in general sense and recent plans conditioned recovery on favorable geologic conditions. If any further mining is to be in this area, MSHA will require making both intake entries travelable and some of the belt and structure would have to be replaced. I agree that further mining in this area would be dangerous and most likely too expensive to rehabilitate. The reserves left in the pillars and the two barriers were never included in the recoverable reserve base as far as I can determine and Genwal not required for further coal recovery in this area. The sealing should go forth and revisions to the R2P2 for this area will be covered in an approval for mine-wide revisions recently submitted.

Inspection Addenda

Entry Date: 1/24/2005

Comments: After the inspection was completed, a question about the in-mine water monitoring well MW-7, located near the back end of Main West, was raised. Apon inquirey, this well was stopped monitoring in 2002 with the consent and knowledge of DOGM due to dangered off area from pillar failure. The well was only 40 feet deep into the Starpoint sandstone and the well did not flow. A pipe cap was place on the well and no notes of any water inflow was recorded. We conclude that sealing Main West will not adversely affect any aspects of the abandoned monitering well.

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

National Institute for
Occuptional Safety and Health
Centers for Disease Control
and Prevention (CDC)
200 Independence Avenue, SW
Washington, DC 20201

September 28, 2007

The Honorable Edward M. Kennedy
United States Senate
Washington, D.C. 20510-6300

Dear Senator Kennedy:

I am writing in response to your letter of September 19, 2007 requesting an "analysis, using ARMPS and LaModel, of retreat mining in the North and South Blocks, Main West of Crandall Canyon."

Please find enclosed an analysis pertaining to the evaluation and control of coal bumps using the ARMPS and LaModel tools.

If you should have any questions regarding the technical analysis contained in the enclosed, please contact Jeffrey Kohler, Ph.D., at 412.386.5301.

I am also sending the enclosure to Senator Murray who co-signed the September 19th letter with you.

Sincerely,

John Howard, M.D.
Director

JH/jh
enclosure

EVALUATION AND CONTROL OF COAL BUMPS

Office of Mine Safety and Health Research
National Institute for Occupational Safety and Health
Centers for Disease Control and Prevention
U.S. Department of Health and Human Services

September 28, 2007

INTRODUCTION

There is general agreement that the immediate cause of the Crandall Canyon mine disaster was a large coal bump that occurred on the morning of August 6, 2007. Coal bumps, which are sudden, violent failures of highly stressed coal, have been a longstanding safety hazard in some mines in the Southern Appalachian, Colorado and Utah coalfields. Typically, bumps can occur when the roof and floor strata are strong and the mines are under deep cover. Bumps have caused many fatalities in past decades, and were the subject of intensive research by NIOSH and its predecessor agencies. The results of this research were transferred to the mining community, and much of it can be found at the NIOSH mining website. A landmark document describing the results of the research effort is Special Publication 1995-01, which is still considered the fundamental resource on the evaluation and control of bumps.

One thing that the research clearly showed was that the most effective way to prevent bumps is through proper pillar design. Pillars are the blocks of coal that carry the great weight of the overburden above the mine workings (figure 1). Most pillars can be classified as either "production pillars" that are within the mining panel, or as "barrier pillars" that isolate individual panels from adjacent mined out areas. When properly sized, pillars provide "Global Stability" that is a necessary, but not sufficient, condition for creating a safe area for miners to work in. Once global stability is obtained, then artificial supports (like roof bolts) can be installed to provide "Local Stability" and keep the mine roof safely above the miner's heads.

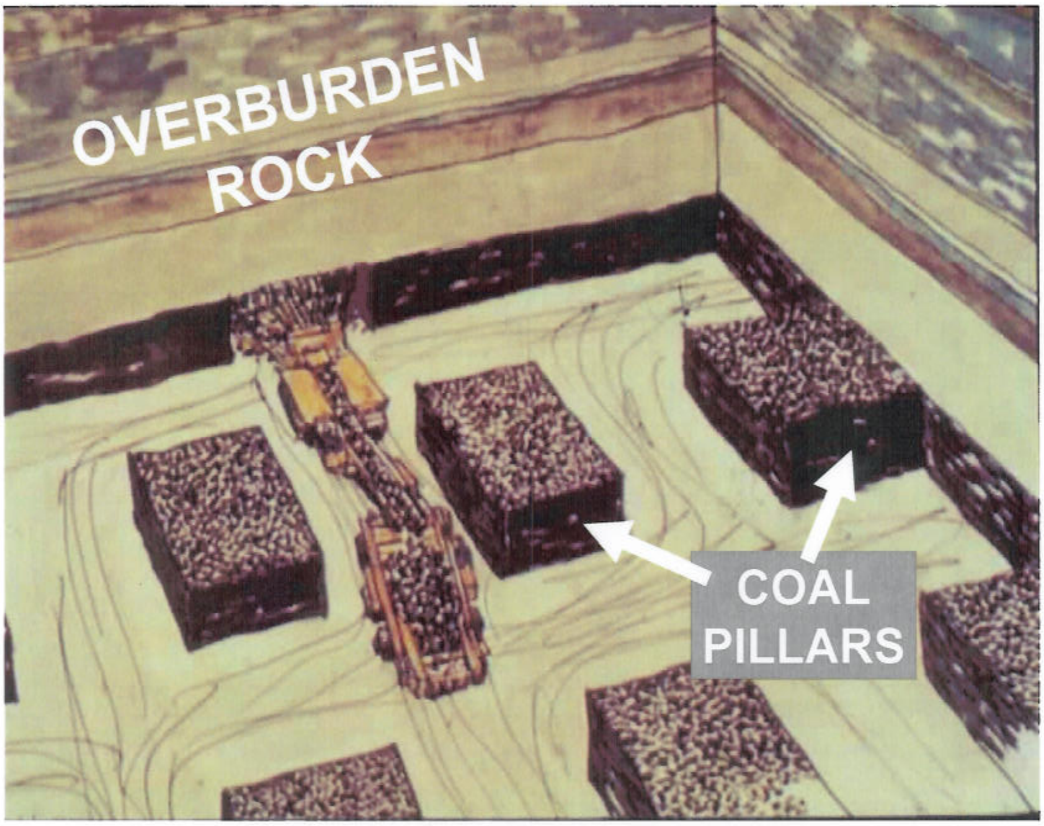

Figure 1. Coal pillars support the great weight of the overburden and provide "Global Stability."

NIOSH has developed several computer programs to help mine planners design coal pillars. For longwall mining, there is the Analysis of Longwall Pillar Stability, or ALPS. For room-and-pillar and retreat mines, there is the Analysis of Retreat Mining Pillar Stability, or ARMPS. Both of the programs are widely used throughout the U.S. The LaModel program was also developed at NIOSH. Its originator, Dr. Keith Heasley, is now Associate Professor of Mining Engineering at West Virginia University.

Both ALPS and ARMPS are considered "empirical" models, because they are based on case histories of full-scale pillar performance in coal mines. Since they are derived directly from real-world data, empirical models do not require a full understanding of the mechanics of pillar behavior. This is a big advantage in the field of rock engineering, because it is usually impossible to obtain reliable field measurements of the strength of the rock, or of the loads that develop during the mining process. Another big advantage is that the output from empirical models is a direct prediction of the likelihood of success or failure, based on actual experience. The disadvantages of empirical models are that they can be unreliable when extrapolated beyond their original data base, and they are usually only appropriate for fairly simple mining geometries.

LaModel, in contrast, is a numerical model that is derived from the fundamental laws of physics. Accordingly, it requires a number of material properties for the coal, rock, and gob that are difficult to obtain. In addition, the output from the model is in terms of stress and rock movement ("convergence"). Therefore, it is usually necessary to employ past experience both in the selection of material properties and the interpretation of the results.

BACKGROUND TO THE ARMPS PROGRAM[1]

ARMPS was first released in 1995, and it made three improvements on earlier pillar design methods. First, it can evaluate a much broader range of the mining geometries and pillar shapes used in room-and-pillar and retreat mining. Second, it can estimate the "abutment loads" that are transferred to the pillars from the "gob areas" that have been mined-out and fully extracted by previous longwall or retreat mining (figure 2). Third, and most significant, ARMPS has been verified with an extremely large data base actual mining case histories. To build the data base,

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[1] Several relevant papers and much additional information are packaged with the ARMPS program, which can be downloaded from the NIOSH website:
http://www.cdc.gov/niosh/mining/products/product6.htm

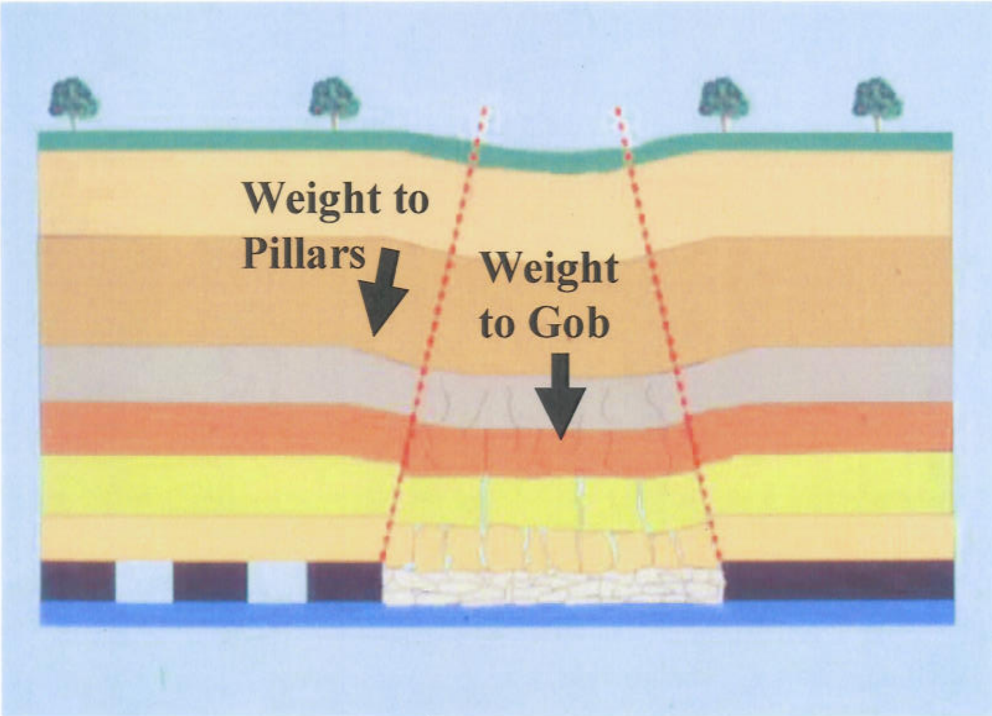

Figure 2. Full extraction mining creates "gob areas" and causes additional "abutment loads" to be transferred to the pillars.

NIOSH researchers visited 68 mines in 10 states, and collected hundreds of examples of successful and unsuccessful pillar designs. In each case, the ARMPS "Stability Factor" (SF) was determined by comparing the estimated pillar loads to the pillars' load-bearing capacity. NIOSH then conducted statistical analysis of the data, and based on the results suggested appropriate SFs to minimize the likelihood of pillar failure in future designs. In essence, these ARMPS SF guidelines make the past experience of a broad cross-section of the industry available to mine planners in a practical form.

The case histories included in the original ARMPS data base were primarily from mines with relatively shallow cover in the eastern U.S. However, because mines under deep cover often have ground control problems that are different and more severe, NIOSH undertook a special research project which focused on refining ARMPS for them. The results were published in

2002. During this investigation, 97 panel design case histories were gathered at 29 mines located in 7 states. In every case the depth of cover exceeded 750 ft. Thirty of the case histories were classified as unsuccessful, in16 of these cases the failure was due to bumps. More than 40% of the case histories, including half of the bumps, were from coal mines in UT and CO.

The study's conclusions are worth quoting in some detail:

> "Only one failure (out of 12 cases) occurred when the ARMPS SF was greater than 0.8 and the barrier pillar SF (BPSF) was greater than 2.0. Conversely, 30 case histories had an ARMPS SF less than 0.8 and a BPSF less than 2.0, and 60% of these cases were failed designs. Of these 18 failed designs, 13 were bump events. In addition, every bump case history collected had a BPSF of less than 1.9. Based on these analyses, conservative design guidelines are proposed as follows:
>
> - When the depth of cover exceeds 1,250 ft, the ARMPS SF of the pillars within the panel should exceed 0.8.
> - When the depth of cover exceeds 1,000 ft, and the area is bump-prone, barrier pillars should be employed that maintain an BPSF of 2.0."

Table 1, which was published with the 2002 paper and subsequently included in the ARMPS help file the complete suggested SF guidelines. In addition, figure 3 illustrates the pillar SF values observed in the data base, while figure 4 shows the importance of the BPSF.

Table 1. NIOSH suggested ARMPS pillar and barrier pillar SFs

Immediate roof rock quality	Weak and intermediate roof strength	Strong roof
ARMPS SF		
650 ft < H < 1,250 ft	$1.5-\left(\frac{H-650}{1000}\right)$	$1.4-\left(\frac{H-650}{1000}\right)$
1,250 < H < 2,000 ft	0.9	0.8
Barrier pillar SF		
H > 1,000 ft	>2.0	>1.5[1] >2.0[2]

[1]Nonbump prone ground
[2]Bump prone ground

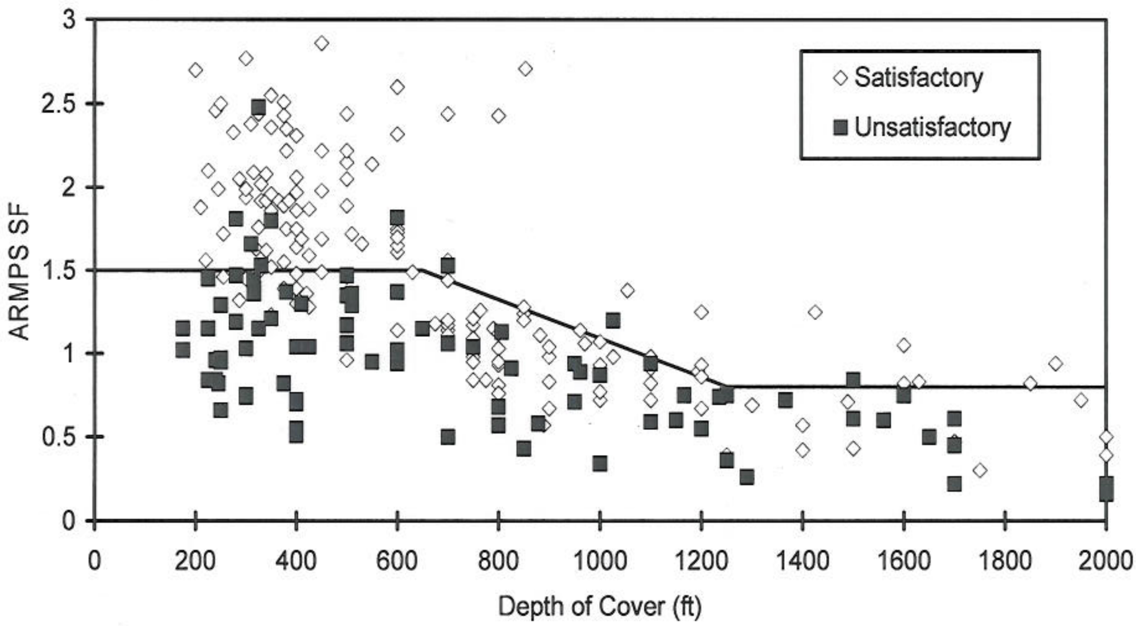

Figure 3. The ARMPS case history data base, including deep cover cases, and showing the suggested pillar SF.

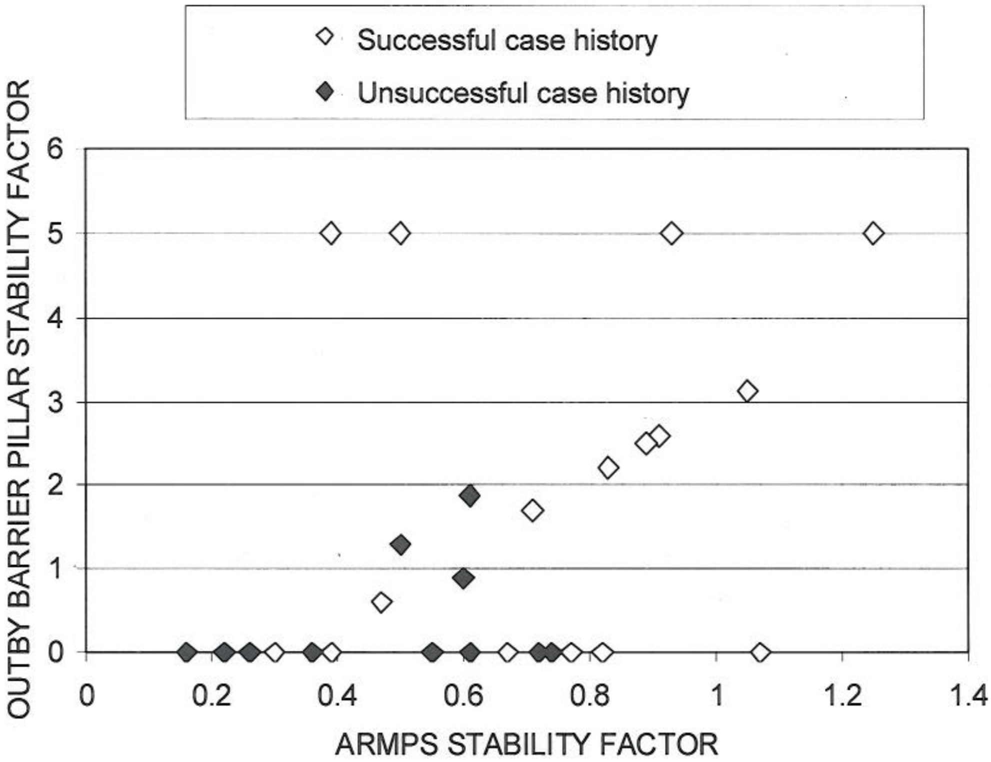

Figure 4. The ARMPS deep-cover, strong roof data base, showing the importance of using barrier pillars for stability. Most of the unsuccessful cases are bumps.

Using ARMPS is fairly straight-forward. On the first interactive screen, the user enters factors including the pillar sizes, the depth of cover, the number of entries, and the entry width are all entered in the one interactive screen (figure 5). In a second screen, factors pertaining to retreat mining are entered. These factors include the dimensions of the gob areas, the width of barrier pillars, and the depth of any "slab cuts" into the barrier. Once the data is entered, the pillar SFs are returned instantaneously. To obtain the BPSFs, the user must page down to the "Barrier Pillar Parameters" output screen.

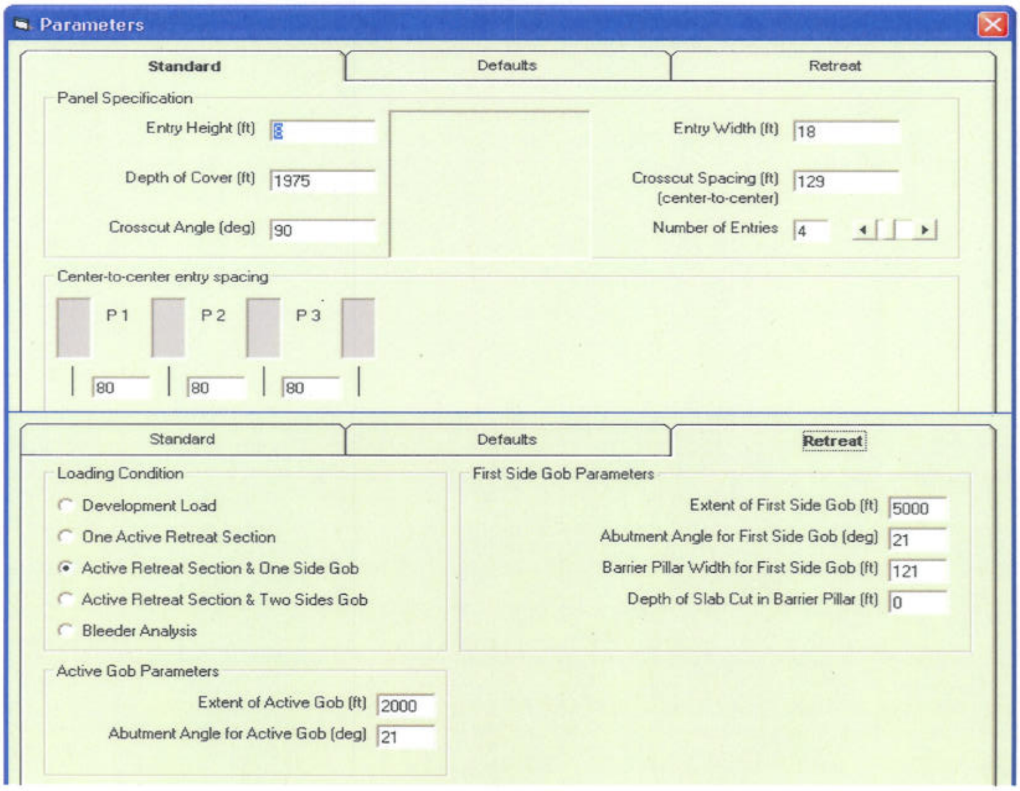

Figure 5. ARMPS input data screens.

The strength of ARMPS is not the sophistication of the calculations; rather it is in the size and comprehensiveness of the case history data base. By using ARMPS, a mine planner can quickly compare a proposed design to what has worked in the past at mines in similar circumstances. However, close study of the data in figure 3 shows that there are many successes with SF less than the recommended values, just as there are some failures with SF that exceed the recommendations. Therefore, the same 2002 paper quoted earlier stated that "the recommendations in Table 1 should be considered as first-approximation guidelines which should be tempered with other site specific variables deemed relevant based on past experience and sound engineering judgment."

Crandall Canyon ARMPS Analysis Conducted by Agapito Associates[2]

The ARMPS analysis conducted by Agapito Associates, Inc. (AAI) is described in the email from Gilbride to Adair dated 8/9/06. The email addresses the initial pillar recovery in the North Barrier only.

With the information provided in the email, NIOSH was able to match AAI's ARMPS results exactly. The NIOSH evaluation identified two issues with AAI's analysis:

Dimensions of the Barrier Pillar: The four-entry development in the North Barrier had created three rows of pillars, leaving a 130 ft solid barrier between those pillars and the longwall gobs to the north. Only two of the pillar rows were to be extracted on retreat, with the third row left to protect the bleeder entry. Since ARMPS does not include bleeder pillars among the mining geometries it evaluates, some engineering judgment is required to consider the bleeder pillars' effect on the overall stability. In AAI's analysis, the bleeder pillars are simply added to the barrier pillar, making the total width of the barrier pillar 210 ft. This results in a very un-conservative analysis, because a solid 210 ft barrier has far more load-bearing capacity than a 130 ft solid pillar plus a row of 60 by 60 ft square pillars. Two more realistic alternatives might have been to:

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[2] The NIOSH analysis relied on two Agapito Associates Inc reports and an email. These are publicly available on MSHA's website, as part of Crandall Canyon's roof control plan., and can be viewed at the following website: http://www.msha.gov/Genwal/CrandallCanyonRoofControlPlan.pdf

- Add the equivalent load-bearing capacity of the bleeder pillars to the barrier, which would result in an "effective barrier pillar width" of approximately 160 ft, or;
- Assume that the bleeder pillars would yield during retreat mining, so that the panel would behave as if all three rows of pillars were extracted.

The effect of modeling a solid 210 ft barrier is to substantially overstate both the BPSF and the pillar SF.

AAI also used 20 ft wide entries in their ARMPS models, rather than the 17 or 18 ft wide entries that were actually planned. This conservative assumption would tend to reduce the calculated pillar SF, but it would not affect the BPSF.

Interpretation of the Results: AAI's discussion of the results of the ARMPS analysis indicates that they focused on the pillar SF as the significant output parameter. They found that their predicted SF for the North Barrier pillar recovery was 0.53, which was less than the 0.9 recommended by ARMPS (actually, the ARMPS recommendation is 0.8 for mines with strong roof). However, they correctly pointed out that "the ARMPS database shows that industry experience is mixed for mines reporting similar SFs at comparable depths." Since historical pillar recovery at Crandall Canyon mine had been successful with pillar SFs as low as 0.37, AAI concluded that "an SF of 0.40 is a reasonable lower limit for retreat mining" at Crandall Canyon. According to the information available to NIOSH, AAI did not consider the importance of the remnant barrier pillar to the overall likelihood of the success of the mining in the North Barrier. The NIOSH interpretation of the case history database made clear that those successful designs with pillar SFs that were less than 0.90 also employed substantial barrier pillars. The AAI ARMPS results would have included a BPSF of 1.50 for the 210 ft barrier pillar they modeled, but this finding is not discussed in their email.

AAI does discuss, in this email and in their other reports, the "need for increased reliance on ground support," including adding extra roof bolts, wire mesh, and Mobile Roof Supports. In addition, the design called for mining narrower entries than in the past, and mining the top coal to eliminate the risk of top coal falls. These precautions indicate that Crandall Canyon did take a number of valuable steps to improve "local stability" during the mining in the North and South Barriers. Unfortunately, such precautions do not reduce the "global stability" risk of pillar failure.

NIOSH ARMPS Analysis

NIOSH has used ARMPS to evaluate, retrospectively, the complete sequence of events leading up to the bump on August 6. It must be noted, however, that the official investigation of the disaster at the Crandall Canyon mine has not yet been completed, so the data currently available for analysis is incomplete and potentially inaccurate. Therefore, the specific quantitative findings presented below should be considered approximate and may be subject to revision.

Figure 6 shows the initial situation before any mining in the North Barrier. The 70 by 70 ft pillars in the mains have an SF of 0.93, which the NIOSH guidelines suggest should be adequate

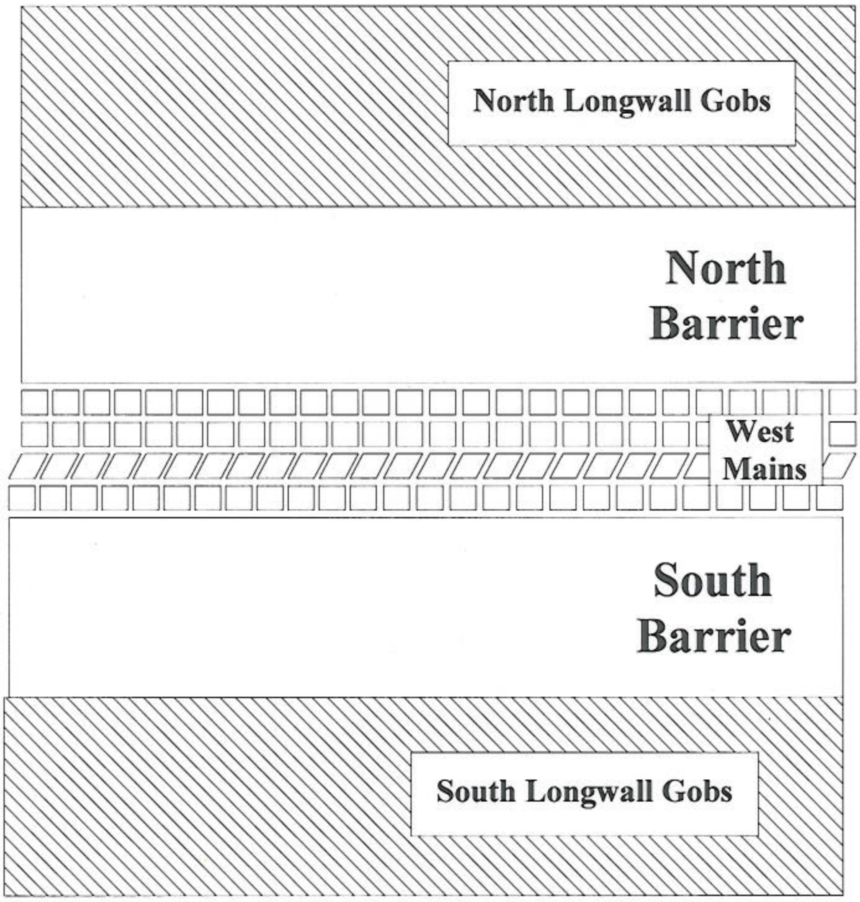

Figure 6. West Mains development as modeled in the NIOSH ARMPS analysis.

for the 2,000 ft maximum sustained depth of cover. The pillars are shielded from the extensive longwall gobs to the north and south by 450 ft barrier pillars whose BPSFs are approximately 4.4.

In figure 7, development has been completed in the North Barrier. The analysis assumes that the pillars in the mains are carrying their full load and are not transferring any to the pillars in the North Barrier development. However, significant abutment load from the north longwall gobs is being transferred across the Remnant North Barrier, resulting in an ARMPS SF 0.46 for the 63 by 73 ft pillars. Most important, the BPSF for the 130 ft wide remnant barrier pillar is just 0.95.

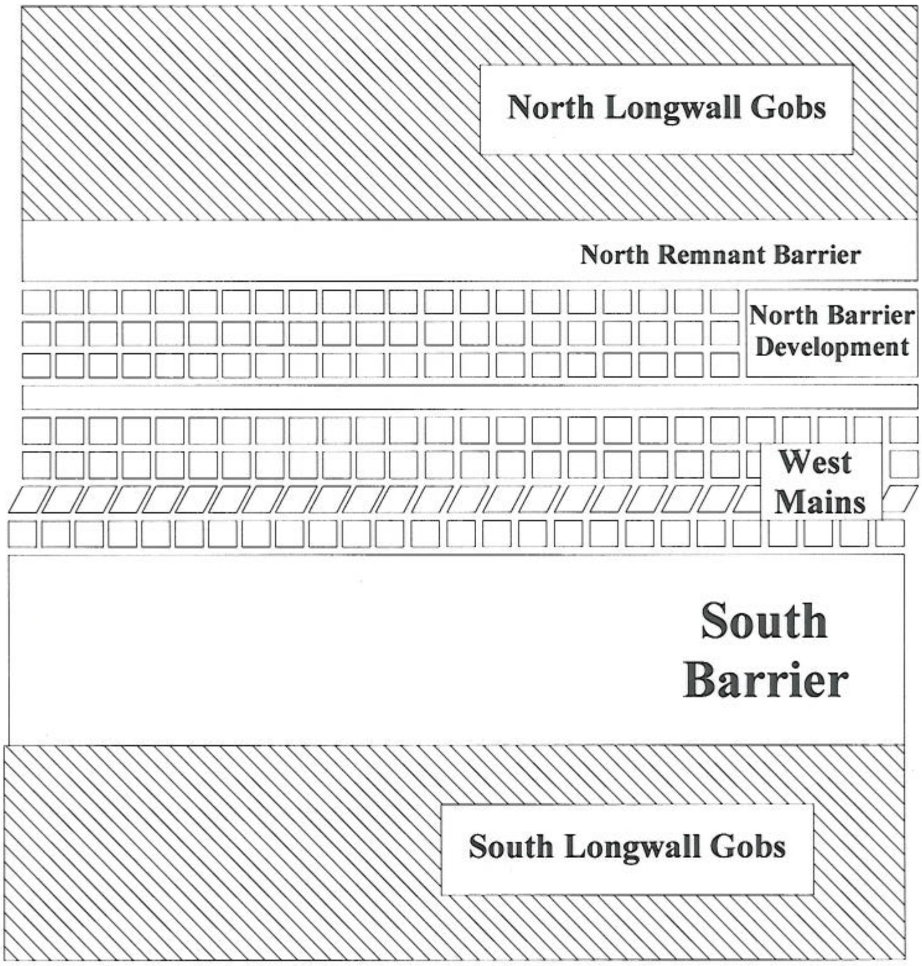

Figure 7. North Barrier development as modeled in the NIOSH ARMPS analysis.

Retreat mining in the North Barrier does not affect the BPSF, but it further reduces the SF of the pillars to 0.32.[3] This was the situation when the bump occurred in early March of 2006 that resulted in the abandonment of the North Barrier pillars (figure 8).

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[3] The NIOSH analysis presented in the text treats the row of bleeder pillar as if it was extracted with the other two pillar rows. An alternative analysis, using an "effective barrier pillar width" of 160 ft with two rows of extracted pillars, has little effect on the pillar SF but increases the BPSF to 1.17.

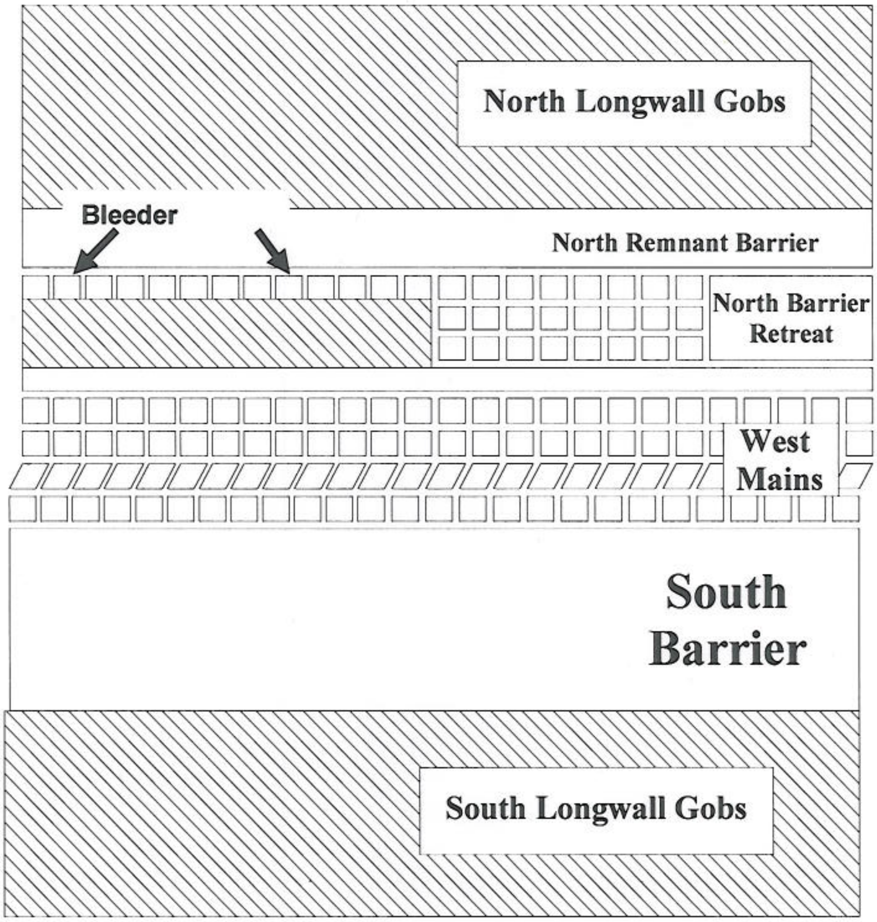

Figure 8. North Barrier retreat mining as modeled in the NIOSH ARMPS analysis. (the model assumes that the row of bleeder pillars has yielded and shed its load).

The development in the South Barrier created pillars that were about 50 ft longer than the ones that had been used in the North Barrier (figure 9). The change increases the pillar SF by only about 15%, to 0.52, because the strength of a coal pillar is largely determined by its least dimension. The remnant south barrier pillar is 10 ft narrower than the one in the north, however, so its BPSF is estimated at 0.91. Pillar recovery, which in the South Barrier involved a slab cut into the remnant barrier, would have further reduced both the pillar SF and the BPSF. Pillar recovery never progressed into the deepest cover portion of the panel, however.

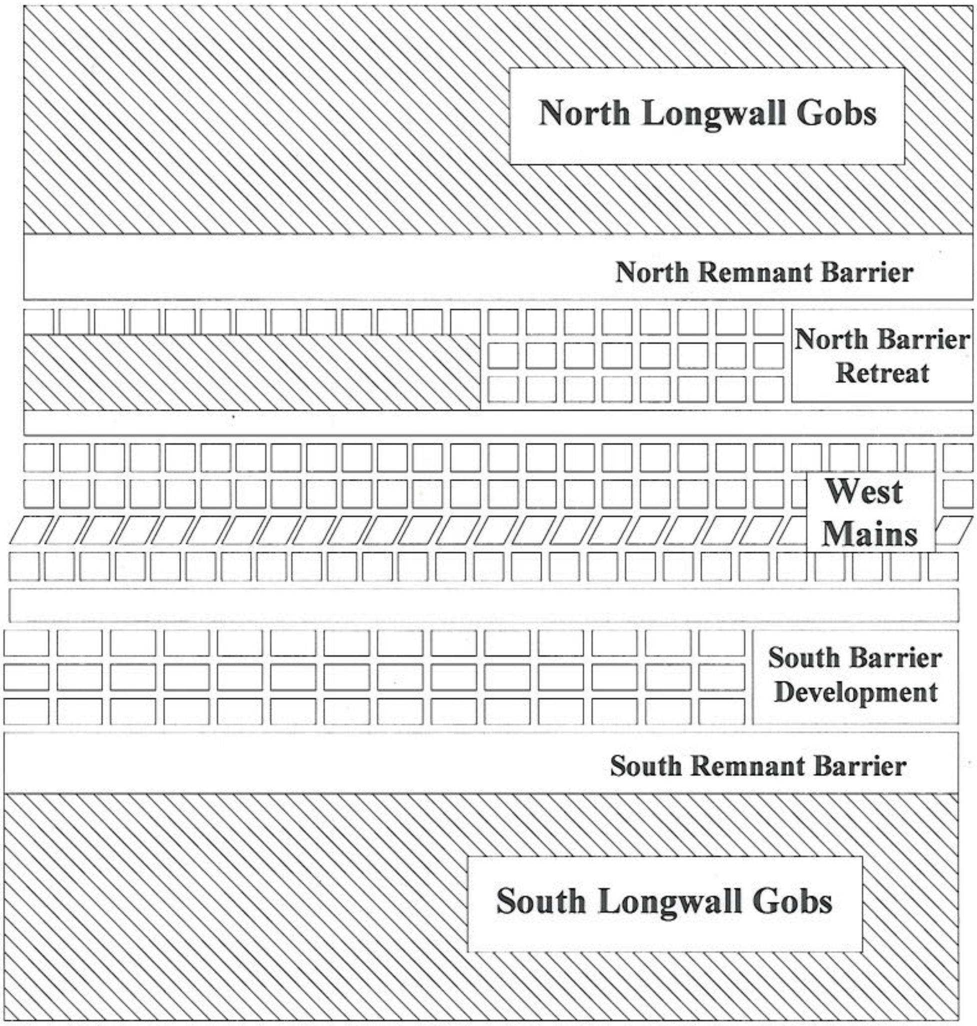

Figure 9. South Barrier development as modeled in the NIOSH ARMPS analysis.

One other consideration in evaluating the South Barrier is the potential for load transfer resulting from failure of pillars in the original West Mains. Once the pillars in the North Barrier have been extracted or failed, an abutment load can be transferred across the slim 50 ft pillar that separates the North Barrier Development from the West Mains. Under these circumstances, the SF for the mains pillars is reduced to 0.71, while the BPSF for the 50 ft barrier is just 0.74. Failure of the pillars in the mains could ensue, and it would result in a second side abutment being applied to the pillars in the South Barrier, further reducing the pillar SF there to 0.35.

In summary, the NIOSH ARMPS analyses indicate that the two remnant barrier pillars were probably the key elements in the Crandall Canyon pillar design. The BPSFs for these structures were about 1.0, significantly lower than the 2.0 guideline that was based on the deep cover case histories collected by NIOSH. A BPSF of 2.0 would have required barrier pillars that were approximately 250 ft wide. Without such substantial barriers, the pillars developed within the original barriers are subjected to substantial abutment loads, which likely exceed their load-bearing capacity.

Crandall Canyon LaModel Analysis Conducted by Agapito Associates

While LaModel is relatively simple compared with some other numerical models (a three-dimensional finite-element program, for example), it is considerably more complex than ARMPS. Unfortunately, because of the time required, NIOSH has not yet completed a LaModel analysis of Crandall Canyon mine, though some preliminary results are attached. NIOSH has, however, conducted a thorough evaluation of the AAI LaModel results, it is possible to identify several reasons why those results proved to be so misleading.

The AAI analysis was conducted in three stages. The initial report, dated July 20, 2006, addresses the development of the initial four entries in the North Barrier. This report contains the most details about the modeling technique. The email of 8/9/2006, in addition to containing the discussion of ARMPS, also shows LaModel results for the planned retreat mining in the North Barrier. The final report, dated April 18, 2007, describes LaModel results for retreat mining in the South Barrier.

The NIOSH evaluation focused on two main areas:

- Values of input parameters used in the models, and;
- Interpretation of the results

As a numerical model, LaModel requires many more input parameters than does ARMPS. These include:

- The stiffness and lamination thickness of the overburden;
- The stiffness of the gob, and;
- The strength and post-yield properties of the coal.

The first two of these affect how the abutment loads are distributed, while the third controls the ability of the coal to carry those loads.

Prof. Heasley, the developer of LaModel, has included default values for these parameters in the "Coal Wizard" and "Gob Wizard" that are incorporated into the program. The coal properties in particular are linked to the coal strength parameters used in ARMPS. These include an "in situ coal strength" of 900 psi, which is the value that was assumed for all the case histories within the NIOSH case history data base. Coal strength has been the subject of controversy for many years, but a comprehensive NIOSH study completed in 1996 showed that ARMPS was much more reliable when a uniform coal strength was used for all seams then it was when seam-specific coal strength values were obtained from laboratory tests.

In their LaModel analyses, AAI employed an in-situ coal strength of 1,640 psi, a value almost twice as great as the LaModel default of 900 psi. It is not clear from the AAI reports how this value was determined. AAI has conducted at least four prior modeling studies at Crandall Canyon mine going back to 1996 (see the footnotes to page 3 of the July 20, 2006 AAI report), and those studies may be the source of the strength value. Since the pillar strength in LaModel is directly proportional to the in situ coal strength, using the 1,640 psi value greatly increases the pillars' load bearing capacity in the model compared to the default coal strength of 900 psi.

AAI used elastic elements when modeling the remnant barrier pillars, according to information available to NIOSH. Elastic elements do not yield at any load, and the model results show unrealistically high stresses in excess of 30,000 psi developing near the edges of the remnant barrier pillars (figure 10, July 20 2006 AAI report).

The high strength of the coal elements employed in the AAI models means that very little load transfer takes place within the models. The same figure 10 cited above shows that the abutment load from the longwall gobs is almost entirely dissipated within 100 ft of the gob edge, leading AAI to conclude that "stress conditions are expected to be controlled by the depth of cover and not by the abutment loads." Within the panels, the AAI models indicate that even yielded pillars carry very high loads. For example, on page 6 of the April 18, 2007 report, a half-extracted pillar within the North Barrier is shown as almost entirely "yielded." Yet the figure on page 5 (reproduced here as figure 10) seems to show that the same remnant is carrying stresses approaching 10,000 psi!

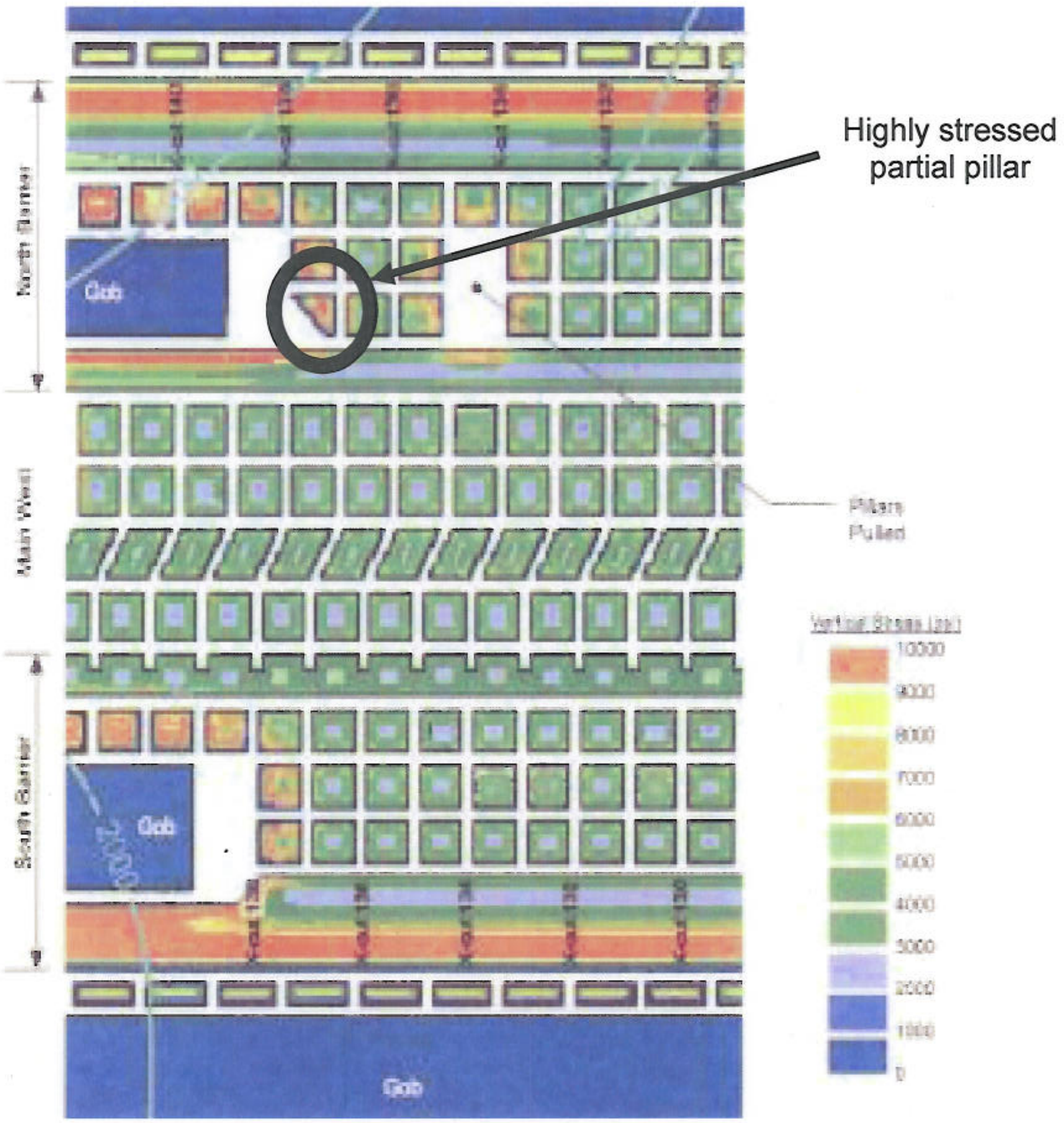

Figure 10. LaModel result shown on page 5 of the AAI report dated April 18, 2007, showing a very highly stressed, partially extracted pillar.

These model results are certainly very different from the empirical rules-of-thumb that have been derived from numerous studies and observations. For example, the standard empirical abutment load distribution formula indicates that more than 400 ft of coal would be required to fully dissipate an abutment load under 2,000 ft of cover.

In the initial report, AAI focused on the "convergence" observed in the model to predict whether mining conditions would be acceptable. Based on analysis of a nearby, historical pillaring area, they concluded that "2.0 inches of convergence is considered an indicator of potential roof and rib instability in the model." It appears that, prior to the bump in March 2007, AAI was using the model mainly to predict areas of "local stability" rather than pillar failure.

The final, 2007 report, does not mention convergence, however. Instead, it correlates "significant yielding," "high stress conditions," and "overloading" observed in the model with potential bump conditions. Longer pillars are judged to reduce risk because they will "help isolate bumps to the face." There is a conspicuous lack of a specific, quantitative design criterion, however.

The AAI LaModel analysis suffered from two limitations. First, without conducting extensive in mine stress measurements or stress mapping, there was no way to confirm whether the distribution of stresses within the model accurately reflected the true situation underground. Second, even if the model's predicted stress and convergence were known to be correct, it might still be difficult to correlate either of them with the potential for success or failure of a particular design. The uncertainties associated with rock mass properties and failure mechanics mean that numerical models must be firmly tethered to past experience if they are to be used to design mine layouts.

NIOSH Preliminary LaModel Analyses of Crandall Canyon

NIOSH has prepared a LaModel grid based on the geometry shown in figure 9. Models have been run to illustrate the effect of changing the coal strength on the results. LaModel provides cross-section plots of the "pillar strain SF," which is a measure of pillar stability but is not directly comparable to the ARMPS SF. Figure 11 shows that when 1,640 psi is used for the in situ coal strength, none of the pillars in the South Barrier have yielded, and in fact they seem to be maintaining pillar strain SFs that are above 1.5. Reducing the in situ coal strength to 1,250 psi reduces the pillar strain SFs to approximately 1.0, which might be considered marginally stable. When the default value of 900 psi is used, all the pillars in the West Mains fail, and a portion of their load is transferred to the South Barrier development pillars. The calculated pillar strain SFs for the pillars in the South Barrier are all below 0.5, and are indicative of significant distress. Clearly the value selected for the in situ coal strength has a very large effect on the model results.

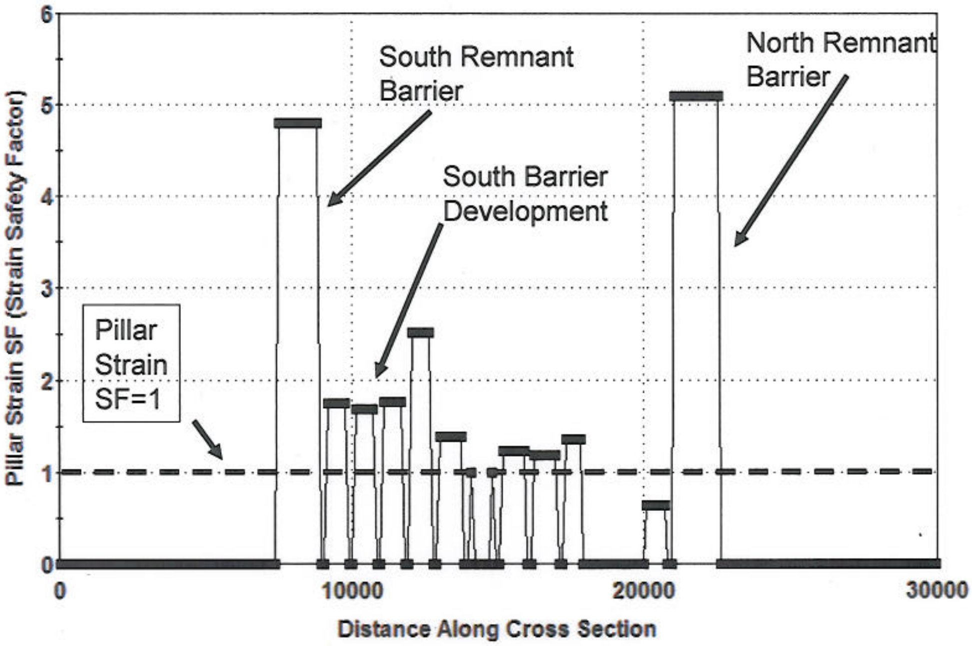

Figure 11. LaModel results with an in situ coal strength of 1,640 psi.
Only one pillar has a LaModel pillar strain SF less than 1.0.

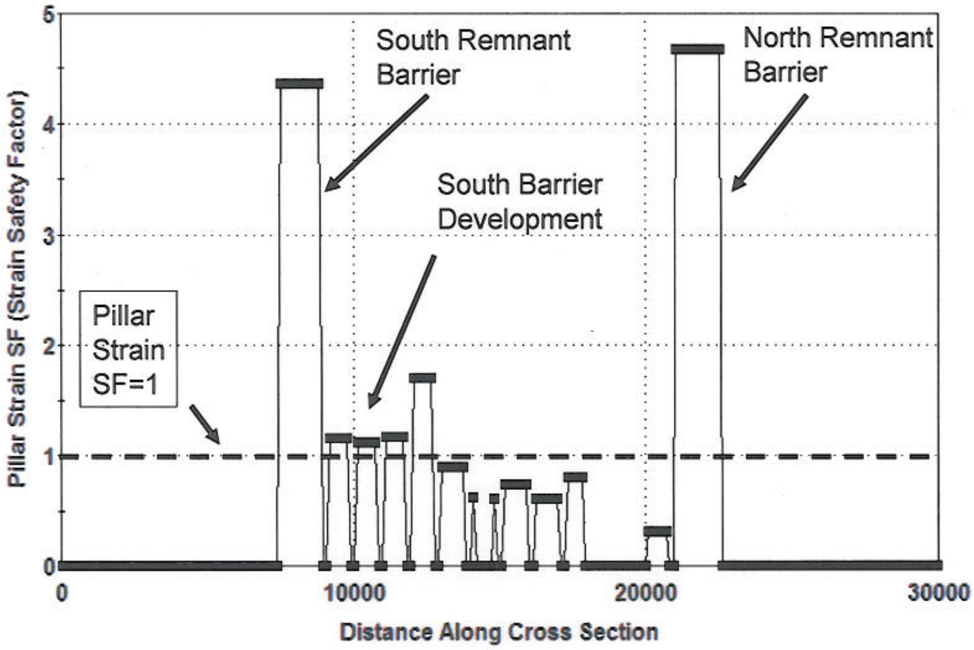

Figure 12. LaModel results with an in situ coal strength of 1,250 psi. Most pillars have LaModel pillar strain SFs of approximately 1.0.

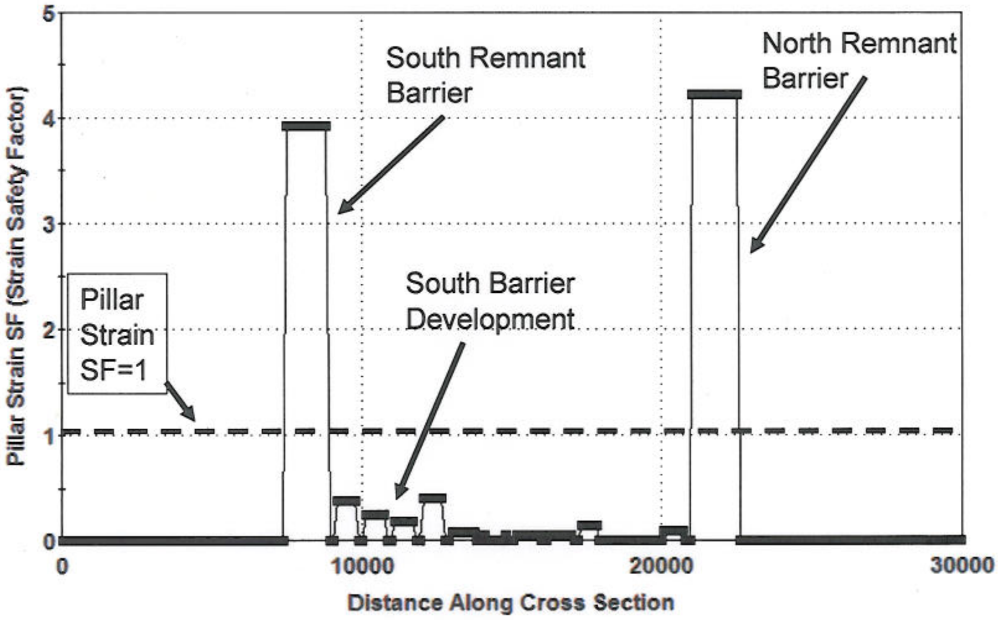

Figure 13. LaModel results using the default in situ coal strength of 900 psi. Most pillars have LaModel pillar strain SFs that are well below 1.0.

Summary

The NIOSH analysis using the ARMPS program indicates that an elevated risk of bumps was present in the Crandall Canyon West Mains area, due to the deep cover and the low barrier pillar stability factors (BPSF) of the remnant barrier pillars. Table 2 shows that the (BPSF) and the pillar stability factors (SF) at Crandall Canyon were significantly lower than the values that NIOSH has published[4]. The NIOSH findings and suggested stability factors are based on its study of retreat mining experience at nearly 30 deep-cover room-and-pillar coal mines.

Table 2. Summary of stability factors

Pillars Evaluated	Figure	Crandall Canyon ARMPS Pillar SF	NIOSH Suggested Minimum SF	Crandall Canyon Barrier Pillar SF	NIOSH Suggested Minimum SF
West Mains	6	0.93	0.8	4.40	2.0
North Barrier Development	7	0.46	0.8	0.95	2.0
North Barrier Retreat	8	0.32	0.8	0.95	2.0
South Barrier Development	9	0.52	0.8	0.91	2.0
South Barrier Development*	9	0.35	0.8	0.91**	2.0

*Assumes failure of Main West pillars
**For the 50 ft barrier between the West Mains and the South Barrier Development

The consultants employed to evaluate the pillar designs at Crandall Canyon placed their primary reliance on the numerical model LaModel, according to the information available to NIOSH. LaModel's results can be highly sensitive to changes in the material properties, particularly the coal strength. In addition, there are no universal guidelines for relating the output from LaModel to predicted mining conditions underground. For a numerical model to be useful for engineering

[4] Chase FE, Mark C, Heasley KA [2002]. Deep Cover Pillar Extraction in the US. Proc. 21st Intl. Conf on Ground Control in Mining, Morgantown, WV, pp. 68-80.

design, it must provide a reasonably accurate representation of the stress distribution in the mine. Moreover, the ability to rely solely on the results of numerical modeling in mining applications can depend upon the accurate selection of material properties and the interpretation of the model's results. The uncertainties associated with rock mass properties and failure mechanics underscore the value of incorporating case histories and other past experience into the numerical modeling process, and into the design of mine layouts.